RHODIUM - A LONG IGNORED ELEMENT IN COSMO- AND GEOCHEMISTRY. Gerhard Schmidt, Institute of Earth Sciences, Heidelberg University (Gerhard.Schmidt@geow.uni-heidelberg.de).

Introduction: 19 chemical elements have only a single stable isotope: ^{103}Rh is one of them. High quality data of the monoisotopic element Rh, Ir, Ru, and Os from impact melts might contribute to our understanding of the nature of impacting projectiles.

Nebular processes (condensation) and fractional crystallization during core formation of planets have produced some compositional variation in the platinum group element (PGE) chemistry of chondrites and irons. The Ir/Rh element ratio permit the best discrimination between the different chondrite groups due to the large difference in the condensation temperature (T_C = 50%, at 10^{-4} bar total pressure) of about 200 K [e.g., 1-4]. Impact melt rocks are potential carriers of meteoritic material. The refractory metals Os, Ir, Ru, and Rh are abundant in most meteorites but depleted in crustal rocks. For Ir and Os, there is a difference of four orders of magnitude, and Rh three orders of magnitude between their meteoritic and crustal abundances. The Ru/Rh versus Ir/Rh diagram in Figure 1 illustrates that a combination of these elements does permit a discrimination between the different chondrite groups and allows the identification of projectiles from impact craters except carbonaceous chondrites and the IVA iron meteorites La Grange, Yanhuitlan, and Maria Elena (1935), since these cannot be distinguished by Ir/Rh, Ru/Rh and Ru/Ir element ratios.

In this study I review published data of the relatively immobile elements Ir, Rh, Ru, and Os in impact melt samples and there diagnostic element ratios for specific impactor compositions of Morokweng, Clearwater East, Sääksjärvi, Dellen, Mien, Brent, Wanapitei, Popigai, Gardnos, Lappajärvi, and Rochechouart impact craters (Table 1).

Clearwater East, Canada: Impact melts from Clearwater East crater with a diameter of ~22 km have the highest fraction of extraterrestrial component of any terrestrial impact structure. The crater was likely formed by a chondrite [5-11]. However, element ratios of the IVA iron meteorite Gibeon [12] match with melt samples [8][9]. Based on PGE and Ni excesses up to ~1.2 wt.% of a Gibeon-like component or about 7 wt.% of a member of a new chondrite group (H. Palme, pers. comm.) has been identified in the melt (Figure 2). Contrary to an iron (Os/Ir of IIE Arlington do not match Clearwater East melt) or new chondrite, an ordinary chondrite as projectile is preferred by [11] based on Cr isotopic composition. However, [13] measured high Cr of 373 µg/g in the country rock DCW 21-62 from the Clearwater West impact structure, where no meteoric Ir was detected in melt samples. About 300 µg/g Cr were measured in Clearwater East Melt [5,6].

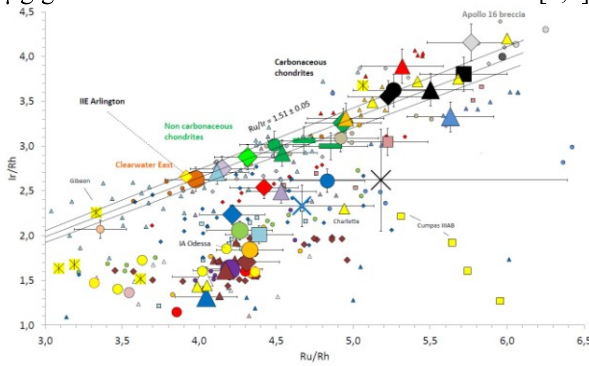

Figure 1. Ru/Rh vs Ir/Rh in impact melts, Earth mantle (n=107, black cross), NC (dark green), CC (black), irons (yellow). Large symbols; mean ratios of totals.

Brent and Wanapitei, Canada: Published low Ir/Rh and Ru/Rh data from Brent and Wanapitei samples [8] match irons (Figure 1, red dots).

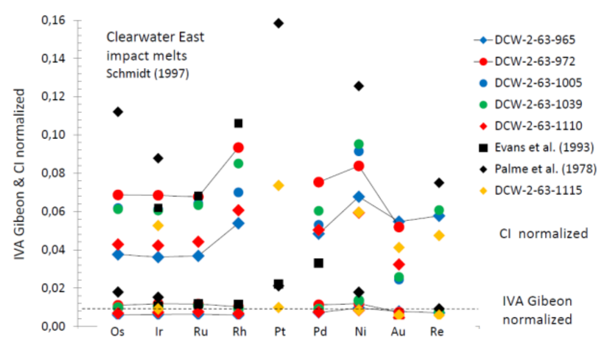

Figure 2. CI chondrite normalized element patterns in Clearwater East melt samples. All elements shown in the lower part of the figure normalized to Gibeon (linear scale !) plot more or less on a horizontal line.

Rochechouart, France: Based on the abundance of Os, Ir, Ni, and Pd in melt samples and subchondritic Os/Ir ratios a IIA magmatic iron asteroid fragment is favoured as projectile type by [14]. [15] report "The projectiles for Rochechouart and Sääksjärvi do not appear to be chondritic in composition but instead stem from fractionated asteroid fragments (Janssens et al., 1977; Palme et al., 1980; Schmidt et al., 1997)". [15] further report "The PGE patterns of IA and IIIC iron meteorites are identical to the element patterns in the impact melt rocks of Rochechouart and Sääksjärvi". Contrary, based on ^{53}Cr excess an ordinary chondrite is favoured by [11]. These authors estimated about 3 wt.% of a chondritic component in the melt. However, Ru/Rh and Ir/Rh from Rochechouart [15] match melt rocks from Apollo 16 landing site [16], IA, IIC, IVA, and ILD 83500 irons [17] (Figure 1, brown diamond).

Popigai, Siberia: Up to 2.31 ng/g Ir were measured in impact melt samples from the ~ 100 km diameter Popigai impact crater in Siberia, one of the largest craters on Earth [18]. Around 0.2 wt.% meteoritic contamination have been identified in homogeneous impact melt samples based on PGE concentrations (no Os data). An L chondrite was identified as the most likely impactor [18]. Enrichment of H-chondritic chromite grains in Italian ejecta layers are interpreted by [19] as likely unmelted fragments of the Popigai impactor. According to [20] chromites in chondrites and iron meteorites cannot be distinguished by their chemistry. Ru/Rh and Ir/Rh mass ratios in Popigai impactites disagree with chondrites (Figure 1, blue diamond).

Lappajärvi, Finland: [11] report that Lappajärvi interelement correlations together with Cr isotope data make an H chondrite the most likely projectile type. An H chondrite is also proposed by [21]. Lappajärvi sample L-L2 has a Cr content of 93 µg/g [22]. 120 µg/g Cr for L-L2 kärnäite (impact melt rock) was determined by [11]. These authors report "The data thus clearly suggest an ordinary chondritic projectile, with about 30% of extraterrestrial chromium in the melt rock". For comparison, the upper crustal content of Cr is 92 ± 17 µg/g [23]. However, the 23 km Lappajärvi crater was probably produced by a member of a new chondrite group, as was possibly Clearwater East. Melt samples have low Ru/Rh and Ir/Rh unknown from meteorites (Figure 1, light blue triangle).

Conclusion: Ir/Rh and Ru/Rh ratios in melt samples from impact craters allows the differentiation of projectile types, except carbonaceous chondrites and some IVA iron meteorites which have similar Ir/Rh, Ru/Rh, and Ru/Ir. Diagnostic ratios of Ir, Rh, Ru, and Os in impact melts from Clearwater East and Rochechouart impact craters contradict projectile identification by Cr isotopes. The Ir/Rh mass ratios as an indicator for the heliocentric distance increases with increasing ε^{100}Ru anomalies [24]. ε^{100}Ru values from melt samples might have the potential to shed light in controversial projectile identification. However, as shown by [25] ordinary chondrites and IVA iron meteorites cannot be distinguished by ε^{100}Ru values.

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Table 1. Terrestrial impact structures with diameters > 1 km. A reappraisal of impactor types based on Ir/Rh, Ru/Rh, Ru/Ir and Os/Ir in melt samples and fossil meteorites.

	Locality	age (Ma)*	crater diameter (km)*	type of impactors Chondrite	Iron	projectile remnants	
1	Popigai Siberia	36.63 ± 0.92	100	(a) H or L-chondrite	(b)		(a) Tagle & Claeys (2005); (b) this work
2	Wanapitei Canada	37.7 ± 1.2	7,5	(c) chondrite or iron	(b)		(c) Evans, Gregoire, Grieve et al. (1993); (b) this work
3	Boltysh Ukraine	65.80 ± 0.67	24		iron		Schmidt (1997)
4	Chicxulub Mexico	66.052 ± 0.043	180	carbonaceous chondrite (CV, CO, or CR)		x	Evans, Gregoire, Grieve et al. (1993); Kyte (1998)
5	Lappajärvi Finland	77.85 ± 0.78	23	(d) H-chondrite or (e) new chondrite	(b)		(d) Tagle, Öhman, Schmitt et al. (2007); (e,b) this work
6	Mien Sweden	122.4 ± 2.3	9		iron		Schmidt, Palme & Kratz (1997)
7	Dellen Sweden	140.82 ± 0.51	19		iron		Schmidt, Palme & Kratz (1997)
8	Morokweng South Africa	146.056 ± 0.018	70	LL-chondrite		x	McDonald, Andreoli, Hart & Tredoux (2001); Maier, Andreoli, McDonald et al. (2006)
9	Rochechouart France	206.92 ± 0.32	23		(f) (IIa); (b) (g) non-magmatic IA, IIIC		(f) Janssens, Hertogen, Takahashi, Anders & Lambert (1977); (g) Tagle, Schmitt & Erzinger 2009; (b) this work
10	Brent Canada	458–453	3,8	(h) chondrite or iron	(b)		(h) Evans, Gregoire, Grieve et al. (1993); (b) this work
11	East Clearwater Canada	470–460	22	(i) new chondrite group	(b)		(i) Palme (2019) pers. comm. (b) this work or new chondrite group
12	Gardnos Norway	546 ± 5?	4,8		non-magmatic		Goderis, Kalleson, Tagle et al. (2009)
13	Sääksjärvi Finland	602 ± 17	6		(j) magmatic (g) non-magmatic IA, IIIC		(j) Schmidt, Palme & Kratz (1997); (g) Tagle, Schmitt & Erzinger (2009)
	total			2	10 ± 1		

*Age data and crater diameter compiled by [26], see references therein.